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U.S.
Department of Energy

ERDA Materials Coordinating
Committee

February 1978

Energy Research and Development Administration's (ERDA) Materials Coordinating Committee (EMACC)*

Annual Report for Fiscal Year 1977

*The Function of the Committee Under ERDA Has Been Transferred to the U.S. Department of Energy

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Washington, D.C. 20545

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CHAIRMAN'S REPORT

The ERDA Materials Coordinating Committee (EMACC) completed its second year of activity in Fiscal Year 1977. Authorization has been received to continue activities in the Department of Energy as the Energy Materials Coordinating Committee. The Committee normally meets for two hours each month to exchange information, discuss materials R&D issues in the energy program, and hear presentations by members and guest speakers on topics of current and general interest.

A list of Committee members for the year is given in Table I. At nearly all meetings, ERDA staff in addition to the Committee members participated. Overview presentations were given by the following divisions at monthly meetings: MHD, INDUS, NR, GE, STOR, and MFE. The number of invited speakers from outside organizations was increased over the previous year because of Committee interest. The following six invited speakers gave presentations this year:

(1) L. Kukacka, Brookhaven National Laboratory, "Cement and Concrete Technology."

(2) E. DiMarzio, National Bureau of Standards, "The Impact of Polymer Science and Technology on the Energy Problem."

(3) R. Jaffee, Electric Power Research Institute, "Overview of EPRI Fossil and Advanced System Materials Programs."

(4) M. K. Booker, Oak Ridge National Laboratory, "A Computerized Mechanical Properties Data Storage and Retrieval System."

(5) R. Bradt, Pennsylvania State University, "Ceramics for Structural Applications."

(6) E. W. Shuster, Heppenstall Company, "Refining of Large Steel Ingots."

Summaries of the talks were included with minutes of Committee meetings.

A major project during the year was to conduct a study and prepare the report, *Survey and Analysis of Selected Topics Within the Energy Research and Development Administration's (ERDA) Materials Research and Development Programs*, DOE/ET-0006. At the beginning of the study, five topics were selected on the basis of size of effort ERDA-wide and the number of divisions with a programmatic interest. A sixth topic, Hydrogen in Materials, was included in the report because the information was available from an earlier study. The topics and the EMACC Panel Leaders in charge of compiling information were:

(1)	Structural alloy development	A. P. Litman (NRA)
(2)	Nondestructive testing	E. E. Hoffman (RDD)
(3)	Structural ceramics development	R. Anderson (INDUS)
(4)	General corrosion	T. B. Cox (MER)
(5)	Erosion and wear	G. R. Garbarini (CONRT)
(6)	Hydrogen in materials	J. H. Swisher (STOR)

Table I. FY 1977 Membership of ERDA Materials Coordinating Committee

Division	Representative
Energy Storage System (STOR)	James H. Swisher, Chairman
Geothermal Energy (GE)	Robert R. Reeber, Executive Secretary
Industrial Energy Conservation (INDUS)	Robert Anderson
Biomedical and Environmental Research (BER)	Robert L. Butenhoff
Electrical Energy Systems (EES)	A. David Allen
Environmental Control Technology (ECT)	Jerry Counts
Materials and Exploratory Research (MER)	Thomas B. Cox
Military Application (MA)	Cdr. Frank W. Hughes
Nuclear Research and Applications (NRA)	Arnold P. Litman
Conservation Research and Technology (CONRT)	Gail R. Garbarini
Magnetohydrodynamics (MHD)	Alan W. Postlethwaite
Buildings and Community Systems (BCS)	Kurt W. Riegel
Solar Energy (SE)	Michael Maybaum
Reactor Development and Demonstration (RDD)	Eugene E. Hoffman
Procurement (P)	Leland Sparks
Naval Reactors (NR)	Robert H. Steele
Basic Energy Sciences (BES)	Donald K. Stevens
Laser Fusion (LF)	Joel Weiss
Magnetic Fusion Energy (MFE)	Klaus M. Zwilsky

Table II. Materials R&D Budgets for FY 1977

Division	Budget, $Millions
Buildings and Community Systems (BCS)	0.2
Conservation Research and Technology (CONRT)	1.0
Electrical Energy Systems (EES)	2.5
Industrial Energy Conservation (INDUS)	3.1
Energy Storage Systems (STOR)	3.7
Materials and Exploratory Research (MER)	5.3
Magnetohydrodynamics (MHD)	2.7
Nuclear Research and Applications (NRA)	10.0
Reactor Development and Demonstration (RDD)	20.5
Laser Fusion (LF)	1.0
Military Application (MA)	64.9
Naval Reactors (NR)	35.0
Basic Energy Sciences (BES)	52.8
Geothermal Energy (GE)	4.0
Magnetic Fusion Energy (MFE)	9.7
Total	216.4

A small contract was awarded by the Chairman to the Oak Ridge National Laboratory for assistance with the study.

The second major activity during the year was to compile a set of program summaries from member divisions for use in this report. In the following sections, summaries are included for all divisions except Solar Energy, Procurement, Biological and Environmental Research, and Environmental Control Technology. In many of the summaries, funding levels for materials R&D are estimates rather than well-defined values because in several engineering divisions the materials effort is not easily separated from engineering development.

The materials R&D budgets in FY 1977 for the divisions that contributed to the report are summarized in Table II. Note that the total does not correspond to all the materials R&D sponsored by ERDA; some activities are supported by divisions that are not members of EMACC and, as mentioned above, a few EMACC-member divisions did not participate in the study.

An election for the FY 1978 EMACC Chairman was held in August, 1977. The new Chairman, Robert R. Reeber, served as Executive Secretary in FY 1977.

James H. Swisher
1977 Chairman
ERDA Materials Coordinating Committee

ASSISTANT ADMINISTRATOR FOR CONSERVATION

Division of Buildings and Community Systems (BCS)

The Consumer Products and Technology Branch activity is a major thrust of the Division of Buildings and Community Systems program and includes research, development, and demonstration activities in energy conservation that

- accelerate the efforts of private industry,
- complement the efforts of private industry,
- foster the acceptance of energy-saving technology,
- maximize the effectiveness of energy use,
- minimize adverse socio-economic and environmental impacts.

The broadly stated objective of the Consumer Products and Technology Branch (CPT) is to encourage and manage research, development, and demonstration (RD&D) of new energy-conserving technologies in heating, cooling, and ventilating equipment and systems; lighting and windows; appliances and other consumer products; controls; materials; telecommunications; and diagnostic equipment used to determine the efficiency of energy use in buildings.

Materials

The materials program concentrates on the technologies necessary to reduce thermal losses or gains in residential, commercial, and industrial buildings through the use of materials. While the emphasis is on interior and exterior insulation for residential and light commercial buildings, insulation of ducting and piping systems is also of interest. The intial emphasis has been on development of cost-effective refit systems that offer promise for early recovery of installation costs through energy savings.

The insulation industry is composed of many competing segments, e.g., fiber glass, rock wool, cellulosic materials, and closed cell foams. The RD&D program will be directed toward identifying potential improvements and effecting improvements in each segment to achieve large National energy savings. Also, RD&D will be considered in such ancillary areas as vapor barriers and infiltration. A close working relationship will be established with industry to enlist its guidance in shaping the development of programs consistent with National energy conservation goals.

Projects

Assessment of Thermal Insulation Materials for Building Applications (existing project, Dynatech Corporation). The purpose of this project is to compile and assess data on existing thermal insulation materials. The project will encompass the analysis of the properties of building thermal insulation materials, including manufacturing and marketability, testing and performance, and code restrictions.

Development of Retrofit Outside Wall System for Insulating Masonry Commercial Buildings (contractor to be determined). The objective of this project is to develop a urea-formaldehyde foam insulation system to be applied to the exterior of masonry walls of light commercial buildings, using rigid standoffs and metal lath to contain the foam. The exterior of the foam is covered with a fiber-reinforced cement plaster.

Areas of possible future interest, no projects presently planned (contractors to be determined). Other projects under consideration for FY 1978 and FY 1979 include Fire Hazards of Insulation, Insulation Testing and Performance Procedures, Gypsum Foam Insulation, and Vapor Barrier Assessment.

The FY 1977 funding level was $150,000, and the present budget allocates $400,000 for FY 1978.

Division of Conservation Research and Technology (CONRT)

The Materials and Fabrication Technology (MFT) Category of CONRT provides supporting technology for development of more efficient energy conversion systems that have multifuel capabilities. MFT Category projects include:

- Insulation Materials
  - Encourage development and more effective use of improved thermal insulation by the private sector.
- High-Temperature Materials
  - Investigate new high-temperature materials for advanced conversion systems.
- Polymers and Reinforced Plastics
  - Investigate new lightweight and durable materials for transportation systems.
- Advanced Development, Planning, and Analysis
  - Identify, evaluate, and formulate new concepts for materials and fabrication technology.

Research and development findings from these projects will support the following ERDA program objectives:

- Industry Conservation
  - advanced insulation materials for commercial use by 1978-80
  - plastics recycling by 1982-85
- Buildings Conservation
  - advanced insulation materials, by 1978-80
- Transportation Conservation
  - ceramic turbines by 1985-88
  - lightweight materials by 1980
- Electric Power Generation
  - materials for thermionic converters (by 1985) and for high-temperature filters (by 1980-82)
  - ceramic turbines by 1990

The total MFT Category is funded at $1.02 million in FY 1977 (including INDUS and NSF funding).

1. Insulation Materials

FY 1977 Funding: $0.19 Million
Contractors: ORNL, CRANE

The project objective is to reduce the energy used in industrial processes and in space heating and cooling by encouraging the development and use of improved insulation materials.

About 27% of the total energy usage in this country [20 EJ (19 quads)] is associated with the heating and cooling buildings. Application of thermal insulation could result in a reduction of up to 30% [6.0 EJ (5.7 quads)] in this usage by the year 2000. Near-term (1985) savings are estimated to be about 3.2 EJ (3.0 quads).

In the industrial area, the potential for energy savings through effective use of insulation was estimated to be about 1.6 EJ (1.5 quads) per year for the six largest energy-consuming industries (by the year 2000). The near-term potential (1985) is about 0.8 EJ (0.8 quad).

A recent assessment of commercially available insulation materials indicates:

- performance is not adequately known;
- combustion risks are not completely evaluated;
- testing and installation techniques are not well developed;
- certain materials are deficient in performance;
- consumers are, in general, unaware of the favorable cost/benefit ratios derived from insulation.

In consideration of both the energy savings potential and the current problem areas related to accelerated use of insulation materials, the CONRT initiative will focus on:

- cooperating with industry to obtain realistic in-service performance data on insulation systems and to develop test procedures, equipment, and facilities for the generation of reliable thermal performance data;
- technically supporting a national energy policy wherein capital investment incentives would be provided to accelerate the application of insulation systems;
- sponsoring Government-Industry workshops for open discussion of needs, problems, solutions, plans, etc.
- initiating insulation materials projects for different temperature ranges, which have the following objectives:
  - Improve insulation for cryogenic processes [5 to 170 K (-450 to -150°F)], including superconducting electric power transmission lines and liquefied natural gas storage;

- improve low-temperature insulation [-100 to +100°C (-150 to +210°F)] for food processing and storage, building insulation, and low-temperature process heat applications;

- improve intermediate-temperature insulation [100 to 510°C (210 to 950°F)] for power generation using steam;

- improve high-temperature insulation [above 510°C (950°F)] used in combustion processes, such as in turbines and high-temperature furnaces, and, where possible, in the ceramics and metal-producing and -processing industries.

2. High-Temperature Materials

FY 1977 Funding: $0.68 Million
Contractors: ORNL, AMMRC, SRI, SOLAR

Current energy conversion devices are relatively inefficient, averaging less than 30% efficiency. Although some improvement could be realized by developing more efficient components, any major increase in conversion efficiency will require increasing the temperature range through which the particular thermodynamic cycle extracts useful work. Since the lower temperature of the cycle is generally limited by the cooling source (i.e., ambient air, river water, etc.), higher operational temperatures are clearly needed to improve conversion efficiency.

State-of-the-art materials are now operating near their maximum useful temperature limit. New materials are required. The purpose of the high-temperature materials program is to develop such promising new materials for energy system applications and, when necessary, to develop processes for the fabrication of required components.

Specific goals are:

- develop materials concepts for ceramic engine components;
- develop materials which will allow increasing the turbine engine operating temperature to 137°C (2500°F) in the near-term and 1650°C (3000°F) in the longer term;
- develop alloys and protective coatings for improved corrosion and erosion resistance in the high-temperature environment associated with turbines, high-temperature batteries, and thermal energy storage;
- develop ceramic materials and coatings for the protection of thermonic converter emitters and collectors;
- develop materials for heat exchangers and other high-temperature devices;
- develop specification requirements and testing techniques for high-temperature materials;
- develop fabrication methods for commercial application.

3. Polymers and Reinforced Plastics

FY 1977 Funding: $0.01 Million
Contractors: Ford, P.I.A.

Polymers and composite materials can provide higher stiffness and strength per unit weight, can make lighter structures and better insulators, and can be fabricated at lower cost and/or energy than competing metallic materials. Additionally, polymeric materials are or can be made compatible with many of the environments encountered by advanced energy conversion, storage, and utilization systems.

Specific project objectives are:

- To develop lightweight materials, both polymers and composites, which will reduce vehicle weight by 30% by 1990. Specific applications for electric and hybrid vehicle manufacturers will be included as well as combustion-powered vehicles. Improved crash properties development will be included.
- To develop polymers and low-cost composites for heat exchangers by 1990.
- To extend the life cycle of plastic materials by scrap recovery processing and to develop separation and conversion processes.
- To assess the polymer processes that use petroleum-base feedstock to ascertain those alternate sources for polymer production that require development.
- To develop testing techniques and specification requirements for polymer and composite materials.

4. Advanced Development, Planning and Analysis

FY 1977 Funding: $0.14 Million
Contractors: ANALY-SYN, NAS, TRW

Almost every systems-level energy R&D problem is ultimately or in part a materials problem. Also, totally new energy systems concepts are possible whenever new materials become available. There is, therefore, a strong need for planning and analysis to determine when and what kind of new materials and fabrication technology are required to speed development of improved energy conversion systems. Project objectives are to provide:

- analysis of costs and benefits of alternative materials and fabrication techniques;
- exploratory R&D into promising materials and fabrication techniques for possible new system concepts, e.g., high-temperature filters;
- planning for future material and fabrication needs (e.g., the availability of raw materials in 1985 may generate a demand for new structural or insulating materials).

Division of Electric Energy Systems (EES)

The vast quantity and numerous types of materials required for the production of electrical equipment to meet expanding electrical energy demands poses a major long-lead-time problem area for electrical energy systems. Coupled with other driving forces — such as esthetics and scarcity of land for transmission rights-of-way, among others — materials research has become an integral part of many development projects of the Electric Energy Systems Division. Topical areas with materials aspects are summarized as follows:

1. Compact Overhead Lines and Towers

   FY 1976–1977 Funding $275,000
   Contractor: C. T. Main,
   Objective: Evaluation of new insulation materials, support concepts and design technologies for overhead ac and dc lines.

2. Advanced Transformer Technology

   FY 1976–1977 Funding: $508,604
   Contractors: GE, Universities
   Objective: Develop technologies associated with advanced transformer design concepts, combining the application of sheet wound coils, compressed gas, polymeric film insulation, and separate sealed cooling system into the design of a power transformer. The objective is to further develop and refine the technology required to produce a power transformer with increased MVA ratings, less size and weight, lower losses, and increased mechanical strength.

3. Compact Sub-Stations

   FY 1976–1977 Funding: $968,230
   Contractors: ORNL, GE, WE, Dow Corning, Factory Mutual Research, Universities
   Objective: Investigation of optimized gas mixtures for superior dielectric performance. Efforts will examine the chemical and physical molecular properties of dielectric gases to quantify the insulating properties and dielectric strength of epoxy insulators, will determine the potential use of silicon fluids in transformers to replace PCBs, and will develop test methods for evaluating fire hazards of oils for replacing askarels in transformers and capacitors.

4. High-Voltage DC Terminals

   FY 1976–1977 Funding: $636,750
   Contractors: Phelps Dodge, GE, NBS, Universities
   Objectives: Development of an oil-impregnated laminar dielectric dc cable system and verification of its performance for operation in utility systems at ±600 kV.

Development of an extruded solid dielectric insulation made specifically for dc operation. A number of candidate insulations will be developed, used in the manufacture of ±100-kV cables, and tested.

Evaluate feasibility of photovoltaic method as a rapid, nondestructive technique for characterizing resistivity uniformity of high-power, large-diameter silicon wafers. Development of standardized process monitoring techniques that will result in greatly increased yields of large-diameter wafers is the project objective.

Basic research on dc flashover mechanisms, with particular emphasis on electrical discharge phenomena and the deposition of contamination on energized dc insulators.

5. <u>Advanced Underground Cable Systems</u>

FY 1976–1977 Funding: $11,315,949
Contractors: General Cable, Reynolds Metals, Phelps Dodge, Power Technologies, Brookhaven, NBS, LASL, Intermagnetics General, Airco, Westinghouse
Objectives: The objectives of the numerous projects in this area are:

Development of irradiated crosslinked polyethylene cables.

Optimization of the design and manufacture of solid dielectric cables (rated 138–345 kV) to achieve a significant increase at higher electrical stresses.

Development of 800-kV synthetic cable, and glass-insulated underground cables.

Develop a flexible underground ac superconductivity system in the 60–345-kV range. This system employes Nb_3Sn conductors and a helium-impregnated wrapped type dielectric.

Characterize the structure and dielectric properties of polymer tape insulation for high voltage superconducting tapes.

Research on dynamics of cryogenic helium and heat transfer for superconductivity.

Optimize the bronze diffusion process for producing niobium-tin conductors, and

Development of an understanding of insulation aging characteristics of solid dielectrics.

In FY 1977, the portion of the effort described above that is judged to be materials research and development corresponds to a budget of $2,500,000.

Division of Industrial Energy Conservation (INDUS)

The main goal of the Industrial Energy Conservation Program is to reduce the energy required in industrial processes, and consequently our materials R&D tends to be materials <u>processing</u> R&D rather than properties R&D. Examples include research programs on new alluminum production techniques and improved steel billet heating technology.

Many projects can be described either as materials R&D or engineering, depending on one's point of view. A review of the FY 1978 budget reveals 18 projects that can be classified as materials research. Twelve of these are on metals and the other six are on ceramics, paper, etc. The total budget outlay for these projects was approximately $3,100,000, of which roughly 75% is in the metals area. About 17% of this sum is spent in government or National laboratories, about 7% in universities, and the remainder in industrial laboratories.

The majority of the budget has been allocated to two areas: first, improved aluminum production technology and second, improved iron melting and forming technology. The view within the Division is that in these areas most processes run far below theoretical (first-law) efficiencies and, further, that the tonnages involved are such that the payoff on successful RD&D projects will be large. If the budget is expanded, a number of additional projects in iron and steel will probably be added, as well as projects in a number of other metals. Work in the areas of glass and ceramics is also expected to expand.

Typically, the Division's RD&D has focused on a relatively few projects approaching the pilot plant stage, and our work on these is supported by smaller measurement technology and evaluation projects, which provide input to these few larger projects (e.g., a project in the mathematical modeling of electric arc furnaces supports our continuing interest in improved melting). Project areas are viewed as packages, and the work tends to be organized on process-specific rather than discipline-specific lines.

Division of Energy Storage Systems (STOR)

The classes of materials under investigation by the Energy Storage Division vary from storage media to structural and special-purpose materials. The activities include materials development, fabrication, characterization, and data base compilation. Most of the activities are integrated into component development projects, and materials R&D does not appear as a line item in the budget. Nevertheless it is a vital part of the Energy Storage Program.

The six subprograms that make up the total effort in the Division are

1. Thermal Energy Storage
2. Chemical and Hydrogen Storage
3. Mechanical Energy Storage
4. Superconducting Magnetic Energy Storage
5. Batteries and Electrochemistry
6. Technical and Economic Analysis

The total funding level for materials R&D in FY 1977 is approximately \$3.7 million. Activities for each subprogram are summarized in the following sections.

1. Thermal Storage

FY 1977 Funding: \$1.3 million
Contractors: Rocket Research, Sandia Livermore, EIC, University of Delaware, Institute of Gas Technology, Suntek, Dow Chemical, Monsanto, NRL, Brookhaven

Heat energy is stored through sensible heat in materials, phase changes in materials (mainly melting and solidification), and reversible chemical reactions. Molten salt compositions are being investigated as both sensible and phase-change thermal storage media. Thermal properties, expansivity, and corrosivity are all important properties. A new thrust of the program is the incorporation of constituents that change phase near ambient temperature in materials of construction for buildings. Reversible chemical reactions such as SO_3 decomposition and steam reforming of methane are attractive for long-term storage and heat storage combined with heat transmission. The materials problems are catalyst development and performance and corrosion of container materials.

2. Chemical and Hydrogen Storage

FY 1977 Funding: \$0.9 million
Contractors: Sandia Livermore, Brookhaven, Virginia Polytechnic, NASA Ames, Pratt and Whitney, GE, University of Georgia, Energy Concepts Co.

Work on the behavior of hydrogen in materials includes structural steels or the containment of hydrogen gas, hydrides as storage media, direct reduction of iron-titanium ores to produce hydride-forming alloys, solid polymer electrolytes for producing hydrogen from water, and catalysts for both thermochemical and electrolytic hydrogen production. Additional information on work on the behavior of hydrogen in materials appears in the chapter of the report on that subject. In other projects in chemical energy storage, sensitizers and catalysts are being developed for the storage of solar energy through phase changes in organic compounds. Also molten-salt systems are being evaluated for separating oxygen from air.

3. Mechanical Energy Storage

FY 1977 Funding: $0.4 million
Contractors: LLL, Oak Ridge Y-12 Plant, Johns Hopkins University, Sandia Alburquerque

Mechanical energy storage projects include compressed air, pumped hydroelectric storage, and flywheel development. At present, only the flywheel project involves materials R&D. The principal task is development, fabrication, and evaluation of lightweight composite materials for both stationary and mobile systems. For cost reasons, composites containing either glass or Kelvar fibers in an epoxy resin matrix are receiving emphasis.

4. Superconducting Magnetic Energy Storage

FY 1977 Funding: $0.2 million
Contractors: University of Wisconsin, LASL

Superconducting materials developed in other ERDA and industrial R&D programs are being fabricated and evaluated for the magnetic storage application. A small amount of aluminum alloy development is being done for superconducting cables.

5. Batteries and Electrochemistry

FY 1977 Funding: $0.7 million
Contractors: Argonne, Ford, University of Utah, University of Florida

Lithium-iron sulfide and sodium-sulfur batteries operate at temperatures of several hundred degrees Celsius. Corrosion of container materials is a concern, as are materials for current collectors, separators, and seals. Of special importance is the development of processing techniques to make beta-alumina parts with reproducible properties for use in sodium-sulfur batteries. Several other battery systems are being developed. Improvements in lead-acid batteries are being made, and new zinc-chlorine and more advanced batteries are under study. Materials R&D for these includes electrode materials and new solid electrolytes.

6. Technical and Economic Analysis

FY 1977 Funding: $0.2 million
Contractor: LLL

A project to compile a data base for materials of interest in energy storage is in its second year. Results are now being fed into a computer so that they will be available to all participants in the energy storage program.

ASSISTANT ADMINISTRATOR FOR FOSSIL ENERGY

Division of Materials and Exploratory Research (MER)

The successful development of the advanced coal conversion processes will depend upon the ability of the materials of construction to withstand the adverse environments of gasification and liquefaction processess. The gasification process temperatures range up to 1100°C (2000°F) with pressures of 10 MPa (1500 psi) and damaging gaseous species such as H_2, H_2O, H_2S and CO, while liquefaction temperatures range to 540°C (1000°F) with hydrogen pressures up to 28 MPa (4000 psi).

Currently the data base for the behavior of materials in these complex environments is small, and where data exist, the abilities of commercially available materials to perform adequately are limited. The materials technology base must be expanded to ensure the successful development of the advanced coal conversion and utilization processes.

To achieve the materials data base necessary to develop the advanced coal technologies, a comprehensive research and development program has been established in the following technology areas:

- alloy development,
- refractories,
- corrosion,
- hydrogen in materials,
- mechanical properties at elevated temperatures,
- erosion,
- failure analysis and technology transfer.

1. <u>Alloy Development</u>

FY 1976 Funding: $1.05 million
FY 1977 Funding: $0.725 million
Contractors: LBL, Sandia, U.S. Bureau of Mines, Lockheed

The alloy development program sponsored by MER is directed towards providing new alloys for use in coal gasification plants. The program addresses the question of substituting various alloying elements for chromium while maintaining suitable resistance to oxidation and sulfidation. In addition, the program is endeavoring to produce a structural steel that will not require postweld heat treatment in thick sections for use in field-erected coal gasification pressure vessels. New wear-resistant alloys are also being developed.

2. <u>Refractories</u>

FY 1976 Funding: $2.2 million
FY 1977 Funding: $1.0 million
Contractors: Battelle Memorial Institute, NBS, U.S. Bureau of Mines, Babcock and Wilcox, University of Utah, University of Missouri, Metal Properties Council, Pennsylvania State University, Argonne, Virginia Polytechnic Institute.

The refractories program is designed to provide data on the behavior of commercially available refractories in gasifier environments. Also, the program is developing a systematic technique for designing the refractory linings in coal gasifiers to avoid mechanical failure. The fracture behavior of refractories is also being investigated.

3. Corrosion

FY 1976 Funding: $2.55 million
FY 1977 Funding: $1.05 million
Contractors: Battelle Memorial Institute, NBS, EPRI, University of Missouri, Argonne, Metal Properties Council, GE, Westinghouse, Exxon, Combustion Engineering, University of Pittsburgh.

The corrosion program sponsored by MER evaluates currently available materials in laboratory and plant tests. The program addresses the problems of corrosion in coal gasifiers and quench systems, turbines burning synthetic fuels, and advanced systems for direct combustion of coal.

4. Hydrogen in Materials

FY 1976 Funding: $0.19 million
FY 1977 Funding: $0.29 million
Contractors: Lehigh University, Ames Laboratory, ORNL

The hydrogen effects program sponsored by the Division of Materials and Exploratory Research seeks to define the behavior of existing engineering alloys in the hydrogenous environments encountered in coal liquefaction and gasification processes.

5. Mechanical Properties at Elevated Temperatures

FY 1976 Funding: $1.0 million
FY 1977 Funding: $0.9 million
Contractors: Metal Properties Council, INEL

The mechanical properties program involves laboratory testing of commercially available alloys and weldments under coal gasification environments. The materials being tested are those high-alloy grades that will be used for internal components in gasifiers.

6. Erosion

FY 1976 Funding: $0.8 million
FY 1977 Funding: $0.7 million
Contractors: Metal Properties Council, Argonne, LBL, U.S. Bureau of Mines, NBS.

The erosion program involves laboratory and plant testing of materials exposed to gasifier and liquefaction environments. Hardfacing alloys are investigated for pump and valve applications. All the work is aimed at the erosion of components by the particulate matter in coal gasification environments and the coal-oil slurries encountered in liquefaction.

7. Failure Analysis and Technology Transfer

FY 1976 Funding: $0.50 million
FY 1977 Funding: $0.65 million
Contractors: ORNL, Argonne, Sandia, NBS, Battelle Memorial Institute

The program involves monitoring the operating coal conversion pilot plants for failures, analysis of the failures, prescribing remedies, and disseminating information regarding material behavior in coal conversion and utilization environments. These ends are accomplished by using several failure analysis laboratories coordinated from a central collection point and the publication of a coal conversion materials newsletter.

Division of Magnetohydrodynamics (MHD)

MHD Material Problems

The coal-fired, open-cycle MHD generator has no established precursor in engineering practice. There is, therefore, no directly relevant technology base that can be tapped to provide a firm starting point for development. Despite this, work was started and progress has been made toward demonstration of technical feasibility. The work, so far, has been very useful in identifying basic materials and design requirements and in pointing the way ahead.

Magnetohydrodynamic systems demand a different class of materials than conventional power conversion systems. There is no rotating machinery imposed between the thermal source and the electric power takeoff, as in turbines or internal combustion engine generators. The only moving "part" is the high-temperature, high-velocity gas stream. The emphasis on mechanical properties, elastic and plastic, required in high-speed rotating machinery design, is, therefore, not required by MHD applications. The emphasis instead is on high-temperature electrical, chemical, and physical properties. A disadvantage is that established materials and manufacturing technologies developed for modern, advanced power conversion machinery are not applicable to the MHD designer. Against this, there is a major advantage in that MHD permits much wider exploitation of ceramic technology. The outstanding advancements made in support of nuclear, space, and selected industrial processes is thus available for exploitation by MHD designers.

The MHD combustor materials requirements are: (1) good insulative performance, (2) slag-seed compatability, (3) high-temperature stability, and (4) satisfactory erosion resistance. The generator presents highly selective electrical property requirements in electrodes and insulators. Electronic conductance is needed in the electrodes while the insulators must be highly resistive. Thermal diffusivity requirements are important to both applications and, of course, both must provide durable service in a highly erosive, corrosive slag-seed environment. Air heater (regenerator) refractories will have to combine slag-seed compatibility with thermal shock (thermal fatigue) resistance. Boiler materials must be resistant to severe hot corrosion and erosion conditions. Finally, the slag-seed separating step will require careful tailoring of material properties to fit design requirements.

Stagnation temperatures along the gas stream path will approach 2850K in the combustor and channel.

Development of MHD will lean heavily on ceramic technology. Problems of high-temperature chemical compatibility at both the wall-slag interface and the electrode-insulator and other solid interfaces in the generator construction will be critical.

It is important, in planning detailed materials development evaluations, that the design environment is clearly defined.

Technology Similarities

There are parallels between MHD requirements and certain segments of previous reentry, thermionic, and nuclear materials development.

These earlier programs, in a sense, started from "scratch." Like MHD, there was no established engineered precursor. Material efforts originated, grew, expanded, and adjusted as design decisions required. Progress depended upon close integration of all development elements: analytical design, parametric engineering studies, experimental design evaluation, component fabrication development, etc. Similarly, MHD materials research, development, and engineering must be closely integrated with design and hardware activities to ensure successful development.

At the present stage of MHD development, materials activities may be considered to be mainly in the engineering evaluation phase. Present activities center principally upon screening evaluations of potential materials of construction. Some of the effort is directed toward slag-seed compatibility evaluations. Other activities are directed toward the generation of basic properties data of critical importance to preliminary design. Limited engineering rig evaluation is being conducted. This work is considered as a step toward preliminary development of component materials. Much more intensive work is needed to: (1) determine design and material limitations and (2) to work toward optimization of design configurations, materials, and fabrication.

Design and Material Considerations

Following is a brief description of design constraints that most strongly influence materials evaluation and selection procedures.

A. Combustor

Magnetohydrodynamic combustors face the problems of temperatures approaching 2850°K, high coal slag contents, stream velocities up to 300 m/sec, and the need to minimize heat transfer losses. Classical water wall construction with frozen "slag" insulation on a sacrificial rammed insulation is the expected solution. However, test linings in subscale equipment with both prefired and rammed linings in magnesia, zirconia, magnesium chromite, etc., are being evaluated. Transpiration cooling designs are also being considered, based on 1600°C preheated air as the "cooling" medium.

B. Generator

1. Insulation

Insulation requirements of first-order design function concern are:

- Continuous voltage standoff — 30 V
- Maximum transient standoff — 90 V
- Rapid heat dissipation (high thermal diffusivity)
- High-temperature electrochemical stability with seed-slag
- Good thermal shock resistance
- No surface-connected porosity
- Long life
- High-temperature structural stability
- High-temperature compatibility with electrode materials

Typical Conditions

- Surface temperature up to approximately 2000°C
- Continuous exposure to slag and seed
- High heat flux (up to 3 MW/m^2)
- High fluid velocities up to 2000 m/s

Materials Under Test

- Dense MgO
- Dense Al_2O_3
- Castable Ceramics
- Boron nitride
- Magnesium chromite spinel
- Magnesium aluminate spinel

2. Electrodes

Electrode requirements of first-order design function concern are:

- Electric current transport
- Slag-seed compatibility
- High thermal diffusivity
- High resistance to oxidation (anode) and potassium-calcium (cathode)
- High-temperature structural stability
- Compatibility with adjacent insulator

Typical Conditions

- Current density — 10 kA/m^2
- Hall field — 3000 V/m
- Temperature (surface) up to 1700°C
- Heat flux — up to 4 MW/m^2
- Electrochemical oxidation (anode)
- Dynamic slag-seed coating
- Electrochemical K and Ca Attack

Materials Under Test

Ceramics

- Magnesium-chromite spinel with up to 30 mol % Fe_3O_4
- $FeAl_2O$-Fe_3O_4 spinel

- o Doped $LaCrO_3$
- o ZrO_2-CeO_2
- o ZrO_2-Y_2O_3
- o ZrO_2-CeO_2-Ta_2O_5

Metals

- o Copper and copper-base alloys
- o Nickel base
- o Cobalt base
- o Iron base
- o Refractory-metal base

(Note: It should be pointed out that high-temperature ceramic electrode materials are in direct engineering test competition with lower temperature metallic electrodes.)

C. Air Heater

The air preheaters for the base-line 2000-MW MHD plant are projected to be of the regenerative type and directly heated by the downstream gases from the MHD channel. These brickwork honeycombs will be alternatively exposed to the hot combustion gases containing coal ash particles and potassium salt vapors and liquid droplets and to the incoming air. Materials and designs for this rigorous service are being tested under DOE contracts. The best performance so far has resulted with magnesia-base materials. Chrome magnesia and spinel-bonded magnesia have been tested in simulated cycling service at temperatures up to 1850^0K (2800^0F).

D. Summary of Relevant Work Breakdown Structure and Contractors

In the MHD program, the work breakdown structure does not define any element in which materials work is separated from component design and performance and durability testing. Certain general categories with significant materials aspects can be identified as design properties and design support engineering component research and to a lesser extent component engineering and development.

Contractors

ANl, PERC, BNWL, NBS, AVCO, Westinghouse, GE, Fluidyne, MERDI, MIT, Mississippi State University, Stanford University, UTSI Montana State University, Montana College of Mineral Science and Technology, University of Tennessee Space Institute

The funding level for the activities classified as materials R&D as opposed to engineering design and fabrication is estimated to be \$2.7 million.

ASSISTANT ADMINISTRATOR FOR NUCLEAR ENERGY

Division of Nuclear Research and Applications (NRA)

Materials research and development programs in NRA are presently being conducted under the auspices of the Office of Technology Development and Special Projects and the Office of Reactor Programs. The materials programs are focused on development and/or characterization of fuels, structural materials, and graphites for gas-cooled reactors; fuels, materials, and components for isotopic heat sources; selenide-base thermoelectric conversion materials, and long-range-ordered alloys for nuclear engineering components and power systems. In addition, a new program was initiated in 1977 on TRIP steels for energy absorbing snubbers and restrainers for protection during seismic events. In FY 1977 the total materials activities were funded at $10 million. A summary of these programs follows.

Gas-Cooled Reactor Materials Programs

1. Fuels, Fuel Element and Core Development

FY 1977 Funding: $3.65 million
Contractors: ORNL, General Atomic Co.

The major objectives of the program are:

a) to establish fuel product specifications to ensure that fuel performance criteria are met in service;

b) to provide fuel performance models needed in reactor core design and safety analysis for accurate prediction of fuel performance during normal, transient, and accident conditions; and

c) to verify fuel specifications, fuel performance predictions, and reactor core design techniques through statistically significant tests of reference fuel designs in test reactors and in operating HTGRs over the full range of HTGR operating conditions.

The program during FY 1977 involved continuing laboratory and irradiation testing of coated particle fuels, fuel rods, and fuel element components. The major capsule irradiation program involving experiments in the HFIR, ORR, and GETR test facilities and the postirradiation examinations was completed. Summary reports were issued covering fuel kernel migration, design bases for the reference fertile fuel particle system, analysis of available fuel rod thermal conductivity data and analysis of the results of all irradiation tests conducted to date.

2. Structural Materials

FY 1977 Funding: $1.2 million
Contractors: ORNL, General Atomic Co.

The major objective of the structural materials program is to develop materials property data required for design of HTGR plant components. This includes fatigue of alloy 800, studies of impure helium effects, qualification of load-bearing ceramics and fibrous insulation, determination of aging and cold work effects, and determination of weld properties.

In FY 1977 significant progress was made in the evaluation of the effects of simulated reactor environments on the reference primary circuit materials (alloy 800, 2-1/4 Cr-1 Mo steel, and Hastelloy X). Creep testing in controlled-purity helium was extended for 2-1/4 Cr-1 Mo alloy and for Hastelloy X. The generation of baseline lowcycle fatigue data for alloy 800 (in air) was completed.

Exposure of unstressed specimens of reference and candidate structural materials in controlled purity helium was extended and testing of these materials in the new high-temperature steam corrosion loop was continued.

3. Graphites

FY 1977 Funding: \$1.1 million
Contractors: General Atomic Co., ORNL

The major objectives of the Gas-Cooled Reactor Graphite Programs are as follows:

a) to evaluate and identify graphites with sufficient radiation stability to perform satisfactorily as core, core support and reflector components in current and future HTGRs;

b) to develop specifications and standards to ensure reproducibility of graphites over the entire HTGR program;

c) to develop data on graphite performance necessary for design, safety analysis, and licensing; and

d) to validate graphite structural design methods and failure criteria.

In FY 1977 the graphite development activities emphasized the procurement and characterization of reference and candidate core graphites, exposure of irradiation capsules in the ORR, preparation of standards, and prooftesting of graphite component structures. The irradiation program showed that the reference near-isotropic material has significantly superior dimensional stability over the earlier reference anisotropic material. The first of a series of graphite creep irradiation experiments was examined and reported.

Efforts to develop graphite standards resulted in the preparation of an ASTM-recommended procedure for methods of testing HTGR graphite components and the drafting of an ERDA standard for the procurement of near-isotropic graphite for fuel and reflector blocks.

Technology Development and Special Projects Programs

1. General Purpose Heat Source Project

FY 1977 Funding: $1.47 million
Contractor: LASL

At the beginning of Fiscal Year 1977 the Plutonium Fuels and Materials Development Program was reoriented to the General Purpose Heat Source Project with LASL assigned responsibility as lead laboratory. This responsibility includes the design, development, and proof of the technology readiness for flight development of a general-purpose plutonium-fueled heat source in time for a 1983 space mission. The heat source will have the following attributes.

1. Highly modular design enabling utilization of the heat source, with a minimum of modifications, for space and terrestrial applications in static and dynamic conversion systems, for space shuttle or ground launching;

2. Improved safety characteristics as exemplified by a safety index goal of 10^{-6} or less;

3. Improved performance and lower weight with a goal of 34 W(t)/kg (75 W(t)/1b) and 0.46 $MW(t)/m^3$ [7.5 $W(t)/in.^3$];

4. Improved reliability as proven by systematic analysis plus confirming tests on full-size fueled modules;

5. Lower indicated fabrication costs as compared with the present Multihundred Watt isotope heat source.

In 1977 the Project completed eight conceptual designs and subjected these designs to a series of analyses, which will reduce the number of designs to three or four for trial by experiment and additional analyses.

2. Advanced Isotope Power Fuels

FY 1977 Funding: $0.13 million
Contractor: ORNL

The objective of the Advanced Isotopic Power Fuels Program is to continue to provide a reduced level of effort on $^{244}Cm_2O_3$ and container materials leading to a systematic closeout of this program. Emphasis in FY 1977 was placed on starting a key compatibility and mechanical properties test series and completion of a study on terrestrial applications of the curium and strontium isotopes.

3. High-Temperature Alloy Development: Physical and Mechanical Metallurgy

FY 1977 Funding: $0.7 million
Contractor: ORNL
Objective: A major objective of this program is to develop special alloys for both space and terrestrial isotope power systems involving hostile environments. Noble metal alloys such as Ir, Pt-30% Rh-8% W, and Rh-Ru have been emphasized as a basic effort as a result of their inherent stability in contact with graphite or isotopic fuels at temperatures to 1440°C. Advanced facilities have been developed under this program to permit creep and stability testing of refractory metals, noble metals, or superalloys at high temperatures in CO, CH_4, inpure helium, or vacuum.

During FY 1977 a family of long-range-ordered alloys was identified, which show a five- to sevenfold superiority in both ductility and creep strength relative to Hastelloy X at 900°C. The new alloys are inherently low in vapor pressure and have signficantly higher moduli than commercial superalloys. Work to date has concentrated on compositions for service to 1000°C in impure helium or vacuum environments.

4. TRIP Steels for Energy Absorption Restrainers for Protecting Reactors in Seismic Events

FY 1977: $0.16 million
Contractor: LBL

Commercial steels exhibiting the TRIP phenomena (strain-induced phase transformation) are being evaluated for energy absorption in new devices (snubbers, pipe hangers, etc.), for protecting reactors from seismic events. The program includes measurements of the total energy absorbtion in cyclic plastic strain under ambient conditions normal to reactor operations. On-site inspection of the new devices will be augmented by transformation of the steels from a nonmagnetic to ferromagnetic structure when activated by plastic strain.

5. Strontium-90 Heat Source Development

FY 1977 Funding: $0.3 million
Contractor: PNL

The objective of the Strontium Heat Source Development Program is to develop the data required for qualification and licensing of $^{90}SrF_2$ from the Hanford Waste Encapsulation and Storage Facility (WESF). Utilization of the $^{90}SrF_2$ will be as fuel in heat sources for terrestrial and undersea isotopic power conversion systems. In FY 1977, a portion of the long-term compatibility tests with WESF-produced fuel was evaluated. Continued progress was made in determining the effect of aging of candidate superalloy container materials on mechanical properties.

6. Heat Source Component Development

FY 1977 Funding: $0.52 million
Contractor: Battelle-Columbus Laboratories

The objective of this program is to develop improved helium vents, impact members, and ablative members (reentry heat shields) for use with isotopic heat sources. In developing these components, the program is emphasizing the mechanical and thermal response of bulk graphites, carbon composites, ceramics, and cermets plus supporting thermodynamic studies. In FY 1977 the design and preliminary verification of a selective helium vent were completed, and high-strain-rate impact studies were completed on candidate graphite materials for a combined impact and heat shield member, e.e., bifunctional ablator.

7. Thermoelectric Conversion Materials Development

FY 1977 Funding: $1.1 million
Contractors: 3M Co., General Atomic

The objective of this program is the development and proof of principle of a new class of higher conversion efficiency thermoelectric materials based on the selenides. In general, the p-type thermoelectric material is composed of copper, silver, and selenium in proportions similar to $Cu_{1.97}Ag_{0.03}Se_{1.0045}$, while the n-type composition is a combination of gadolinium and selenium in proportions similar to $GdSe_{1.49}$. These selenide-base materials derive their useful thermoelectric properties from a unique defect doping mechanism in a nonstoichiometric crystal lattice structure. In contrast to the state-of-the-art compositions, these materials remain extrinsic conductors to 1000°C and have superior thermoelectric material figure-of-merit values.

The program efforts at 3M Co. include alloy synthesis and processing; element, couple, and power module fabrication; thermodynamic stability and chemical compatibility studies; mechanical property characterization; and couple and power module performance evaluations. General Atomic is developing element bonding materials from tungsten- and molybdenum-base alloys and sublimination suppression coatings based on glassy boron compounds, especially oxides, and lanthanum group compounds.

In FY 1977 significant progress was made in n material synthesis and n-leg fabrication. A 54-thermocouple, 25 W(e) test module was placed on test as a precursor to a 100-W(e) ground demonstration system to be tested in early FY 78.

Division of Reactor Development and Demonstration (RDD)

Materials development represents a key item in the program to bring the Liquid Metal Fast Breeder Reactor (LMFBR) into use as one of this Nation's major energy sources. The LMFBR is designed to operate for 40 years under rather severe conditions which include a fast neutron flux in excess of 10^{19} n/m^2s and a high-temperature sodium environment, which removes heat from the reactor core. Materials research and development have been carried on for 20 years in the areas pertinent to LMFBR and consequently the program is in an advanced state. This state can best be described as one of providing materials property data needed for advanced, high-temperature design methods and developing advanced materials that promise longer lives under optimized reactor operating conditions. Most of the materials programs are being directed by task groups formed from contractor personnel and, further, most of the effort has been planned to completion in the form of Program Summaries and Program Plans.

The RDD materials program is divided into five research and development areas as follows:

1. Materials Development
2. Materials Engineering Development
3. Advanced Fuel Cladding Alloy Development
4. Reference Cladding and Duct Development
5. Structures Engineering Development

The total RDD materials program is funded at $20.7 million in FY 1977.

1. Materials Development

FY 1977 Funding: $7.1 million
Contractors: AI, ANL, GE, HEDL, LMEC, NRL, ORNL, WARD

The objectives of this program are to develop the materials and processes that are inherent to a safe, economical, and reliable LMFBR industry. To realize these objectives requires successful completion of five supporting objectives as follows:

- establish operational limits on current component materials and develop advanced structural alloys with longer life at higher stresses;

- provide near-term support for all component interfaces requiring hardfacing and develop improved hardfacing materials and application methods;

- develop more sensitive nondestructive examination methods with remote, automated operating techniques for use on plant fabrication and in-service inspection requirements.

- define the compatibility of LMFBR materials with sodium and aqueous systems and evaluate problems associated with corrosion product mass transfer;
- establish operating life and a design guide for current elastomer seals and provide advanced seals with high-temperature, long life capability.

2. Materials Engineering Development

FY 1977 Funding: $2.9 million
Contractors: AI, GE, HEDL, ORNL, WARD, INEL

The objectives of the Materials Engineering Program are to develop fabrication methods and manufacturing processes suitable for the economical production of reactor plant components in sizes required for large LMFBR plants. The metallurgical effects of these fabrication methods and manufacturing processes on the properties of the materials of construction of LMFBR components will be assessed through limited testing for conformance with Code requirements and to assure the attainment of an adequate component service life. These materials properties will be documented in a handbook useful to designers.

Specific objectives are:

- to develop mechanical properties data for alloy 718 base material given the 950°C (1750°F) commercial heat treatment and mechanical properties data for alloy 718 base and weld materials given the heat treatment required in welded construction;
- to develop fabrication methods by which large diameter [0.9-1.4 m (36-54 in.) thin wall [13-25 mm (0.5-1 in.)] type 304 and 316 stainless steel welded and seamless pipe, pipe bends, and elbows can be economically fabricated to dimensional tolerances suitable for elevated-temperature service; to determine the effects of these fabrication processes on pipe and fitting dimensional variations including wall concentricity, wall thickness variation, contour, and ovality, which affect mismatch, fit-up, and quality of piping systems;
- to advance welding technology, to improve nuclear plant weldment quality, reproducibility, and inspectability;
- to develop and qualify flexible pipe joints for ASME Code Class 1 service in LMFBR primary and secondary system piping by developing rules for design by analysis, developing methods of fabrication, and conducting design verification testing of subcomponents and test assemblies;
- to determine the effects of sodium and reactor cavity gas reaction products on fatigue and static load cracking behavior and corrosion of stainless steel piping;

- to provide the specification, procurement, and material characterization of steam generator tubes and tubesheets; establish nondestructive testing needs of steam generator systems and to develop nondestructive testing methods to support manufacture and in-service inspection of these steam generators; optimize plant water chemistry to reduce corrosion and fouling of steam generators; and establish the reference design and welding procedures specification for the austenitic stainless steel to ferritic steel transition spool pieces for LMFBR plants;

- to provide an authoritative source of materials properties data on a continuing, updated, state-of-the-art basis, in a form suitable for use by Design Engineers and Materials Engineers responsible for the selection and control of materials and fabrication processes for nuclear plant equipment.

3. <u>Advanced Fuel Cladding Alloy Development</u>

FY 1977 Funding: $3.9 million
Contractors: AI, GE, HEDL, ORNL, WARD

The objectives of this program are to develop fuel cladding and subassembly duct materials that are compatible with providing the option of introducing fuel systems having peak burnup capabilities up to 150,000 MWd/T and doubling times of 10 to 15 years or less by 1986. This objective will be accomplished by means of the following subobjectives:

- to assimilate the materials requirements established for various fuel systems and core designs and to obtain an objective basis for the selection of the optimum duct and cladding materials for specific reactor systems;

- to characterize swelling, in-reactor creep, and postirradiation mechanical properties of currently commercially available alloys, and to identify appropriate control of compositional and processing parameters for optimum alloy performance;

- to develop new alloys that are tailored to specific LMFBR requirements and designed to provide improved creep and swelling resistance with increased ductility and stability;

- to provide a fundamental understanding of the processes that control in-reactor creep and swelling, thereby assisting in the selection of prime candidate commercial alloys and development of new alloys;

- to assess, under representative reactor environmental conditions, the compatibility of advanced cladding and duct alloys with liquid sodium;

- to determine the compatibility of advanced cladding alloys with various fuels under prototypic service conditions;
- to provide fully qualified duct and cladding product forms for in-reactor performance testing and to develop the necessary industrial fabrication technology for production of advanced alloy core components.

4. <u>Reference Cladding and Duct Development</u>

FY 1977 Funding: $3.1 million
Contractors: AI, ANL, GE, HEDL, LASL

The objectives of this program are to develop reference cladding and duct technology for use in early core LMFBR applications. Primary emphasis is on irradiation effects in 20%-cold-worked type 316 stainless steel with supporting technology in the areas of fabrication development, material optimization, and irradiation vehicle development. Specific objectives are as follows:

- to determine the effects of irradiation on flow and fracture behavior under conditions appropriate to reactor transient events, using conventional tensile tests together with tests that simulate LMFBR transient environment;
- to determine effects of irradiation on low-rate deformation using in-reactor test techniques; these tests support steady-state reactor analysis;
- to test and evaluate methods for calculating the damaging effects of prior steady-state and transient strain accumulation on subsequent transient and steady-state performance;
- to determine the volume change caused by neutron fluence and applied stress as well as the interaction of irradiation creep and metal swelling;
- to reduce all material behavior data to equations or graphical displays that are easily utilized in design analysis;
- to establish the basic nature and develop mechanistic models for irradiation effects on mechanical properties and swelling;
- to develop and evaluate various manufacturing processes for cladding and duct and related components and to qualify vendors.

5. Structures Engineering Development

FY 1977 Funding: $3.5 million
Contractors: AI, Agbabian, ORNL, WARD

The objectives of this program are to establish the design technology required to demonstrate structural adequacy and to assure safe and reliable operation of LMFBR components on a practical and verified basis.

- to develop and validate both rigorous and simplified design analysis methods and criteria that adequately account for the effects of complex stress states and loadings at elevated temperatures;
- to develop methods for predicting the behavior of flawed components, margins to failure, and failure modes;
- to develop methods and criteria for seismic analysis;
- to prepare and update codes and standards for use in structural design and seismic analysis of components and structures.

Division of Naval Reactors (NR)

The Materials Research and Development Program in the Division of Naval Reactors is in support of the development and operation of improved and longer life reactors and pressurized water reactor plants for naval nuclear propulsion. In addition, this program supports the Light Water Breeder Reactor (LWBR) currently operating in the Shippingport Atomic Power Station and the Advanced Water Breeder Activity to develop technical information that will assist U.S. industry in evaluating the LWBR for commercial scale applications.

The objective of the materials program is to develop and apply in operating service materials capable of use in the high power density and long life required of naval ship propulsion systems. This work includes irradiation testing of reactor fuel, poison, and cladding materials in the Advanced Test Reactor at the Idaho National Engineering Laboratory. This testing and associated examination and design analysis demonstrates the performance characteristics of existing materials as well as defining the operating limits for new materials.

Corrosion, mechanical property, and wear testing is also conducted on reactor plant structural materials under both primary reactor and secondary steam plant conditions to confirm the acceptability of these materials for the ship life. This testing is conducted primarily at two government laboratories — Bettis Atomic Power Laboratory in Pittsburgh and Knolls Atomic Power Laboratory in Schenectady, New York.

One result of the work on reactor plant structural material is the issuance of specifications defining the processing and final product requirements for materials used in naval propulsion plants. These specifications also cover the areas of welding and nondestructive testing.

The materials program effort applied to the Light Water Breeder Reactor includes irradiation testing of fuel rods utilizing the thorium-uranium-233 fuel cycle, which has the potential for providing appreciably more energy than the current design of water reactors. This testing provides the basis for the development of analytical models for use in calculating the performance of fuel rods in pressurized water reactors.

Funding for this materials program is incorporated in naval projects jointly funded by the Department of Defense and the Department of Energy and the Water Breeder Reactor program funded by the Department of Energy. This funding amounts to approximately $35 million dollars in FY 1977, including about $15 million as the cost for irradiation testing in the Advanced Test Reactor.

ASSISTANT ADMINISTRATOR FOR NATIONAL SECURITY

Divison of Laser Fusion (LF)

The Division of Laser Fusion is sponsoring a research program to develop advanced optical materials to be used in lasers for laser fusion applications. The overall objective of the research is to develop transmitting optical materials with a low nonlinear index of refraction. Experiments and calculations indicate that improvement of current optical materials can more than double the performance of large solid-state laser systems.

Included in the research program sponsored by LF are efforts being sponsored at several industrial organizations to develop improved optical glasses. These glasses are being developed for potential applications as laser rods, laser disks, lenses, windows, polarizer substrates, and Faraday rotators. From experimental and theoretical research performed over the past few years, it appears that glasses with the desired properties for laser fusion applications will be members of the fluorophosphate or fluoroberyllate groups of optical glasses. These materials, although cited in the scientific literature, are not commonly used and have many properties that are dissimilar with the more routinely melted silicate glasses. Therefore, extensive research is necessary to develop and optimize glass compositions for laser applications.

Also being supported in this optical materials effort is a somewhat smaller research program directed toward the development of crystalline materials, principally fluorides, that also have improved optical properties resulting from a relatively small ($<0.6 \times 10^{-13}$) nonlinear index of refraction.

This materials research effort began in FY 1976T and has FY 1977 funding of approximately $1.0 million.

Contractors:

Owens Illinois, Schott Optical Glass, Corning Glass Works, Hoya Optics, Kigre, Sanders Associates, Raytheon

Division of Military Application (MA)

The objectives of the program are to develop the materials and materials technology for National security and defense uses. This includes basic material science, the understanding and development of advanced materials and fabrication technology, and the development of material and processes required to produce nuclear and nonnuclear parts.

The Military Application (MA) Materials Research and Development Program is divided into three major areas as follows under the budget categories of Development Capability and Production and Surveillance:

1. Supporting Research
2. Materials and Fabrication Technology
3. Process Development

The total MA materials program is estimated at $64.9 million in FY 1977.

1. Supporting Research

FY 1977 Estimated Funding: $10 million
Contractors: LASL, LLL, Sandia

The objective of the Supporting Research area is to include material research that is fundamental to weapon development. Work is directed toward development of analytical procedures and nondestructive test methods needed to support ongoing weapon development programs and toward development and characterization of materials. Supporting materials research is required where the design engineer's ability to apply materials is limited by lack of understanding of basic materials phenomena.

Typical research areas include: plutonium and actinide research, chemical high explosives, inorganic material synthesis, chemical characterization support, material characterization studies, surface studies, theoretical material research, equation of state, nondestructive testing, structural materials, and electronic materials.

2. Materials and Fabrication Technology

FY 1977 Estimated Funding: $17.9 million
Contractors: LASL, LLL, Sandia

The objectives of the Materials and Fabrication Technology area are the understanding of advanced materials and their potential application through studies of the mechanisms that influence material behavior, studies of failure criteria, determination of properties, and the development of processes to formulate new materials.

The scope of these activities includes the application of materials to engineering techniques and the development of fabrication technology. This materials program is directed toward providing well-characterized materials for long-term predictable weapons concepts.

3. Process Development

FY 1977 Estimated Funding: $37 million
Contractors: Bendix, Rockwell International, Monsanto, GE, Mason and Hanger, Union Carbide, du Pont

The objective of the Process Development area is the development of material and processes required to produce nuclear and nonnuclear parts. Development work is performed by the production plants on new materials and production processes for weapons concepts in advanced development, engineering development, and production phases.

The scope of the Process Development area includes manufacturing research and development work to improve existing processes for efficiency and safety.

ASSISTANT ADMINISTRATOR FOR SOLAR, GEOTHERMAL, AND ADVANCED ENERGY SYSTEMS

Division of Basic Energy Sciences (BES)
(Formerly Division of Physical Research)

The Materials Sciences subprogram of the Division of Physical Research supports basic materials research in energy-related areas of interest to ERDA. While organizationally the Division of Basic Energy Sciences is located under the Assistant Administrator for Solar, Geothermal, and Advanced Energy Systems, the mission of the Division is to provide the physical research base for all ERDA activities. In addition to the Materials Sciences subprogram, other programs are administered by the Division's Nuclear Sciences, Molecular, Mathematical and Geosciences, and High Energy Physics Offices.

Materials Sciences research is supported primarily at ERDA National Laboratories and universities, and to a lesser extent at industrial laboratories. The research covers a spectrum of scientific and engineering areas of interest to ERDA and is conducted generally by personnel trained in the disciplines of solid-state physics, metallurgy, ceramics, and chemistry. The overall goals of the program are summarized in the following:

1. to advance the understanding of basic structures, mechanisms, and phenomena governing properties and behavior of matter in the condensed state.

2. to provide a foundation for materials technology through the development of basic knowledge in materials-related energy problem areas of interest to ERDA,

3. to exploit the unique capabilities and facilities existing in ERDA Laboratories for conducting National materials sciences programs.

Most of the research is conducted at the ERDA multiprogram laboratories in close proximity to the applied programs. In this manner, the transfer of new information and techniques into technology is facilitated, while at the same time the needs of the applied programs are brought to the attention of the basic research community. Special attention is also given to research capabilities residing in universities. Support of research in universities is undertaken on the basis of research opportunities at these institutions. Here, recognition is also given to the fact that highly trained manpower in the critical area of materials sciences will result whose skills would be oriented toward energy technologies.

Funding for the Materials Sciences subprogram for FY 1977 is $52.8 million in operating budget outlays. The research programs are described in considerable detail in the publication, Materials Sciences Programs FY 1976, available as ERDA publication 76/123. The report also contains a convenient index to various subjects of interest. The FY 1977 edition will be available later in this fiscal year.

Table 1 shows the distribution of funding for the Materials Sciences program as planned for FY 1977, by laboratory. Note that the portion of the program entitled Contract Research is made up of projects funded via the unsolicited proposal route and consists of mostly university projects.

Table 1. Funding by Laboratory

	%
Ames Laboratory	9.6
Argonne National Laboratory	22.6
Brookhaven National Laboratory	10.5
Idaho National Engineering Laboratory	0.2
Illinois, University of (Materials Research Laboratory)	3.1
Lawrence Berkeley Laboratory	8.1
Lawrence Livermore Laboratory	1.5
Los Alamos Scientific Laboratory	1.7
Mound Laboratory	0.4
Oak Ridge National Laboratory	23.3
Pacific Northwest Laboratory	2.0
Sandia Laboratory	1.2
Contract Research	15.8
Total	100.0

The Materials Sciences subprogram is divided into three major categories: (1) metallurgy and ceramics, (2) solid state physics, and (3) materials chemistry. These reflect both the technical content and the primary disciplines employed.

1. Metallurgy and Ceramics

FY 1977 Funding: $23.0 million
Contractors: Ames, Argonne, Brookhaven, University of Illinois, LASL, LBL, LLL, Mound, ORNL, PNL, Sandia, Universities

Under the Metallurgy and Ceramics category, research is conducted to better understand the relationship between materials properties and structure. Understanding this relationship is the key to improving present materials and creating new materials to meet the demanding needs of future energy systems. Important properties of materials such as fracture, plastic flow, superconductivity, corrosion resistance, radiation resistance, and transport phenomena all depend on structure. As our understanding becomes more complete and our ability to create the beneficial structures increases, it will be possible to design materials to meet engineering requirements — a task not always possible at the present time. This research will ultimately enable designers to more accurately predict the behavior of materials and changes in material properties as a function of time, stress, exposure to and a variety of environments. Although basic in nature, the program is centered around research areas deemed to be of greatest interest for energy systems. For example, there is within the metallurgy and ceramic category a strong emphasis on hydrogen effects, radiation effects, high-temperature ceramics, refractory metals, and superconductivity, all important topics for energy systems.

There are five budget details under the Metallurgy and Ceramics category: structure of materials, mechanical properties, physical properties, radiation effects, and engineering materials (to be started in FY 1978).

The structure of materials detail supports research designed to enhance our understanding of the atomic, electronic, defect and physical structure of materials, how they are affected by composition and processing, and how they relate to material properties.

The mechanical properties is concerned with material behavior related to structural integrity requirements of all energy systems. Research in this detail addresses the understanding of strength at high and low temperatures, creep, fatigue, elastic constants, micro- and macrostrain, fracture, and mechanical-chemical effects in hostile environments.

Research in the physical properties detail is directed toward understanding the fundamental phenomena controlling the thermal, optical, and electrical properties of materials, how they can be altered by various heat treatments or other processing steps, and how they are affected by external variables such as temperature and pressure.

The radiation effects detail encompasses research delineating radiation-induced changes of materials properties important to fusion and fission reactors. Reactor problems are centered on materials, and their improvement depends on better theoretical and experimental understanding of defect production, interaction, diffusion, agglomeration, and annihilation at microstructural features, and the resulting structural stability and mechanical properties.

A new budget detail, engineering materials, is being initiated in FY 1978. Its purpose is to support basic research aimed at understanding more fully the fundamental materials science on which engineering systems should be based. Some of the topics to be included in this detail include: friction and wear, mechanics, engineering corrosion and fracture studies, coupling of engineering design with materials sciences, joining and welding, nondestructive evaluation, extractive processes, and the forming and processing of materials. In general, this detail will provide the link to engineering systems by studying more complex materials systems and phenomena.

2. Solid-State Physics

FY 1977 Funding: $21.7 million
Contractors: Ames, Argonne, Brookhaven, University of Illinois, LASL, LBL, LLL, ORNL, PNL, Sandia, Universities

The solid-state physics category is directed toward fundmental research on matter in the condensed state, wherein the interactions of electrons, atoms, and defects are tracked with the purpose of determining the critical properties of solids. These interactions are the ultimate source of all materials properties. Research under this category includes a broad spectrum of experimental and theoretical efforts, which contribute basic solid-state knowledge important to all energy technologies. Accelerated progress is made in this field through the rapid advancements in unique experimental tools and their coupling with high-speed computer systems. Through these efforts, fundamental understanding of matter in the condensed state contributes broadly to characterizing material properties and processes in all energy technologies.

There are five budget details within the solid-state physics category: neutron scattering, experimental research, theoretical research, particle-solid interactions, and engineering physics (to start in FY 1978).

The neutron scattering detail supports research of a unique kind, namely, the use of the neutron as an analytical probe of the properties of solids and liquids. With this probe, fundamental parameters of superconductors, magnets, hydrides, and solid imperfections are determined in a manner that cannot be accomplished by any other technique. The exploitation of this probe is being advanced by recent development of more efficient monochromators and wider use of longer wavelength probes. The bulk of the Nation's efforts in this important area has historically been supported at ERDA laboratories, where the advanced research reactors are in operation.

The experimental research detail is very broad and includes all fundamental investigations, experimental in concept, on liquids and the solids of metals, alloys, semiconductors, insulators, and compounds. The area of high-temperature materials in both metals and nonmetals, especially in relation to MHD electrodes and insulators as well as other high-temperature energy systems, is being pursued. Ion implantation and backscattering research is being used to learn how to improve superconductor and photovoltaic performance. Hydrogen and hydrides are under study through ultra-high-pressure and spectroscopic techniques. Superconductivity is an area being given major attention. Synchrotron light will be utilized in characterizing surfaces with particular relation to catalytic response. Lifetime and recombination processes in important solar materials is under study, and a search is being made for unusual thermal and electrical properties in new materials.

With nearly all these experimental areas, a highly advanced theoretical research detail is closely coupled. A large part of the theoretical effort is directed towards dynamic processes in solids and liquids and requires extensive use of ERDA's most advanced computer complexes.

Under particle-solid interactions, a major effort is under way to correlate the complex effects of particles of different mass, energy, and charge, not only on surfaces but in bulk materials as well. Preliminary measurements of radiation damage in ultrathin metals have revealed results that are consistent with theory for the onset of damage in the early range of the damaging particle traverse.

A new budget detail for FY 1978 has been designated the engineering physics detail. This effort is to fulfill the much needed goal of utilizing solid state physics expertise in engineering research for which it has a unique capability, and in areas where it is now felt a gap exists. Typical of the work to be initiated are research laboratory investigations of novel processing techniques with mass spectrometer-computer control for complex material preparation, such as solar materials and superconducting alloys, where large areas or very long lengths are required. Another area is the extension of cryogenic and refrigeration techniques to new fluid systems that hold promise for the utilization of low-grade heat.

3. Materials Chemistry

FY 1977 Funding: $8.3 million
Contractors: Ames, Argonne, Brookhaven, INEL, LBL, LLL, LASL, ORNL, Universities

The materials chemistry category provides support for research directed toward developing our understanding of the chemical properties of materials as determined by their composition, structure, and environment (pressure, temperature, etc.) and to show how the laws of chemistry may be used to understand physical as well as chemical properties and phenomena. Included, for example, are studies of energy changes accompanying transformations, the influence of varying physical conditions on rates of transformations, and the manner in which the structure of atomic groupings influences both properties and reactivity.

Chemical concepts coupled with physical experimental techniques are used to study the kinetics of reactions of solids and liquids, the interaction and/or penetration of species in adjacent media, corrosion and scaling, and the stability of high-temperature materials of interest to fossil and geothermal technologies. The program also includes research on the chemical thermodynamics of fission products and their interactions with fuels and cladding materials. Electrochemical research important to storage batteries, fuel cells, and hydrogen generation is an important aspect of research supported under this category. Research involving elastomers and polymers is also being pursued.

There are three budget details in the materials chemistry category: structural chemistry, engineering chemistry, and high-temperature and surface chemistry.

Structural chemistry involves studies of a wide variety of problems where a knowledge of the relationship between the atomic structures of materials and their reactivity is required. Important examples of these effects include the influence of different chemical environments on the catalytic properties of metals. Changes in both the crystal and magnetic structures of compounds are correlated with their specific roles in fuel synthesis, for example.

The methods of engineering chemistry are applied to problems that are currently limiting the efficiency of energy conversion systems under fundamental study. An effort is being made to understand the bonding factors responsible for the decrease of stone adherence (structural stability) of naturally occurring and synthetic dolomites used in sulfur-scavenging in the combustion of coal. Studies are under way on investigating the structural and morphological changes that arise during the electrochemical incorporation of lithium into aluminum during charge-discharge cycles of the high-temperature battery. The measurement of equilibria between tritium and candidate blanket materials will be extended to lower pressures to be encountered in fusion devices, and the studies of tritium permeation of oxide films will be studied under steam generator conditions.

<u>The high-temperature and surface chemistry</u> detail includes programs on fundamental studies of the influence of surface properties on reactivity and for the correlation of mass transport and thermodynamic properties of molten salts in high-temperature battery systems. Chemical studies of scaling in geothermal environments will include a search for methods of inhibiting the deposition of salts on the inner walls of pipes. The influence of micro-inclusions such as sulfides on the formation of pits and crevices will be examined to determine whether the presence of these inclusions plays a significant role in the initiation of stress-corrosion cracking.

Division of Geothermal Energy (GE)

Applied materials research and development is part of the Geochemical Engineering program in the Division of Geothermal Energy. The objective of the materials work in the Division of Geothermal Energy is to provide materials for geothermal applications and to reduce the cost of these materials where they have a significant effect on the cost of production of geothermal power. (Materials needs are defined by the heat extraction process and fluid characteristics.) These provide a focus for the specific materials R&D necessary for U.S. geothermal electric and nonelectric utilization. The program evaluates materials needs. These are required for well drilling and completion, control equipment, energy extraction equipment, and disposal equipment. Materials selection for some energy extraction equipment must consider secondary fluid corrosion characteristics (hydrogen embrittlement, stress-corrosion cracking, and other failure modes associated with hydrogen or hydrocarbon instabilities) occurring at equipment operating temperatures. Additionally, the program reviews the materials test plans for the construction of large geothermal projects and demonstrations. Spinoff materials, chemistry, and failure analysis information from all DGE projects are being combined with applied materials R&D results for a site-specific materials design handbook.

The materials technology required for geothermal development is an extension of that developed for other industries. The program is cooperating with various concerned sectors of industry and appropriate National technical societies to set testing and materials specification standards for the geothermal industry.

The total DGE materials program is funded at $4 million in FY 1977. Additional to this is approximately $900,000 for materials selection studies directly related to large project test plans.

The DGE materials program is divided into two research and development areas as follows:

1. <u>Borehole materials</u>

FY 1977 Funding: $2.9 million
Contractors are 10% government-related organizations, 65% industrial, and 25% university or nonprofit organizations.

The objective of the borehole materials area is to provide well drilling and completion materials for geothermal applications. These include well casing, drill bits, drilling muds, cements, packers, cable, seals, and instrumentation needs. The scope of these activities includes (1) definition of materials requirements, (2) evaluation of state-of-the-art materials in the geothermal environment, and (3) the development of new materials where they are required and can significantly reduce the cost of geothermal energy.

2. Energy extraction materials

FY 1977 Funding: \$1.1 million
Contractors are 70% government-related organizations, 10% industrial, and 20% university and nonprofit organizations

These include geothermal electric and nonelectric applications. The objective is to provide materials for control, energy extraction, and disposal subsystems.

Division of Magnetic Fusion Energy (MFE)

Materials represent one of the major long-lead-time problem areas for power-producing fusion systems. Fusion reactors present their own special materials problems related to, but often separate from, those of LMFBRs and other systems. The most severe of these deals with the effects of 14-MeV neutrons and other high-energy particles generated in fusion reactors. This radiation not only results in increased bulk radiation effects) displacement damage, void formation, helium embrittlement) but gives rise to a whole new set of surface-related effects, including neutron and charged-particle sputtering, blistering, and chemical sputtering. Such effects are known, but there is only a modest knowledge about their magnitude. reproducibility, variability with materials, and energy dependence. Other areas that require investigation include potential coolant and blanket materials, compatibility with structural components, welding and fabrication techniques, nondestructive testing, high-temperature design, and adequate electrical insulators. A part of the MFE materials program is the development of radiation facility concepts for testing of materials and components.

The objectives of the program are to develop the materials and technology for commercial fusion power generation. This includes the development of new radiation-resistant first wall structural alloys, as well as the development and testing of other materials such as insulators, moderator and breeding materials, and materials for energy and power-conversion systems. The general requirements have been assessed in various system studies as well as by the MFE Materials and Radiation Effects Branch and are being incorporated into a comprehensive progarm plan. Task groups have been fomed to assess the detailed technical requirements for commercial reactors and intermediate systems and to establish taks and milestones to meet them. A program plan will be available early in FY 1978.

The MFE Materials and Radiation Effects program is divided into five research and development areas as follows:

1. Alloy Development for Irradiation Performance
2. Plasma-Materials Interaction
3. Special-Purpose Materials Development
4. Damage Analysis and Dosimetry
5. Radiation Source Development and Operation

The total MFE materials program was funded at $7.64 million in FY 1977. Five Materials Program Bulletins have been published and are available on request. The titles are as follows:

Bulletin 1: *Overview of Fusion Materials Program*
Bulletin 2: *First Wall Structural Goal for Economic Fusion Power*
Bulletin 3: *Alloy Development to Meet First Wall Structural Goals for Economic Fusion Power*
Bulletin 4: *Plasma-Materials Interaction*
Bulletin 5: *Neutron Radiation Facilities*

Two other bulletins on Special Purpose Materials and Task Groups are currently in preparation.

1. Alloy Development for Irradiation Performance

FY 1977 Funding: $2.70 million
Contractors: HEDL, LLL, LASL, ORNL, PNL, Universities

The objective of the Alloy Development for Irradiation Performance area is to provide the materials development for structural materials that are subject to significant radiation damage. The prime technical objective is the development of a structural material for the first wall and structural elements for the blanket and shield of a commercial fusion power reactor.

The scope of these activities include (1) the definition of material requirements that are needed to satisfy fusion power system design goals, including the Experimental Power Reactor (EPR), the Demonstration Plant (DEMO), and Commercial Fusion Reactors; (2) the evaluation of existing materials to achieve those goals, (3) the development of new materials to achieve those goals; and (4) the development of the materials radiation data required for design, construction, and operation of fusion power systems.

2. Plasma-Materails Interaction

FY 1977 Funding: $2.16 million
Contractors: ANL, General Atomic, ORNL, PNL, Sandia, Universities

One of the objectives of the Plasma-Materials Interaction area is to support the Alloy Development and Irradiation Performance task. The scope of Plasma-Materials Interactions, however, is much broader since the impact of this technical area is very important in near-term confinement systems, such as tokamaks. The approach is to treat the plasma-wall interaction as an integral problem convering both the effects on the plasma and the effects on the first wall.

Specific objectives are:

- to treat surface effects from the standpoints of plasma contamination, wall erosion, and device efficiency;

- to contribute to the solution of problems in confinement experiments over the near term while developing the data base for dealing with possibly more severe problems in reactors;

- to evaluate surfaces as part of a completely integrated system consisting of the plasma and its perimeter, the external blanket, subsystems for vacuum pumping, fueling and ash removal, and possibly bumpers or divertors;

- to develop new materials resistant to surface damage in concert with overall alloy development tasks for commercial fusion power.

3. Special-Purpose Materials Development

FY 1977 Funding: $0.72 million
Contractors: Brookhaven, LASL, ORNL, LLL, PNL

This technical area covers the development of materials other than first wall structural materials described previously. Included are the following materials applications:

- Insulators in structural applications
- Insulators for components such as neutral beams and superconducting magnets
- Moderator and breeding materials
- Materials for heat transfer systems and power-conversion (secondary) systems
- Others as they become identified.

4. Damage Analysis and Dosimetry

FY 1977 Funding: $0.60 million
Contractors: AI, Argonne, Brookhaven, HEDL, LASL, ORNL, Universities

The objectives of the Damage Analysis and Dosimetry area are to characterize available irradition test environments and to establish a basis for predicting materials performance under irradiation in a fusion reactor environment. This will be accomplished by materials irradiation data obtained in fission reactors, accelerator-based neutron test environments, and charged particle irradiations.

The scope of the Damage Analysis and Dosimetry area includes development and application of the methodology and nuclear data base required for characterization of the neutronic test environments, the development of fundamental radiation damage models, the development of methods to account for interactive phenomena in the evaluation of damage structures, the relationship of structure and damage parameters to property changes, and the application of the above to the prediction of material performance in fusion reactor systems.

5. Radiation Source Development and Operation

FY 1977 Funding: $1.46 million
Contractors: Argonne, HEDL, LASL, LLL, MIT

The objectives of this area are to define the radiation environment of fusion reactors and to pursue the development of neutron and plasma sources to simulate this environment for materials testing. Since fusion reactors are not now available for testing, high-energy neutron and plasma sources are needed to develop materials for commercial fusion power.

High-energy neutron sources are based on the deuterium-tritium (DT) reaction to produce 14-MeV neutrons and on the Li(*d*,*n*) and Be(*d*,*n*) stripping reactions to produce a broad spectrum of high-energy neutrons. Two DT neutron sources authorized for construction by Congress are the Rotating Target Neutron Source, RTNS, being built at LLL and the Intense Neutron Source, INS, being built at LASL. The RTNS is designed for 14-MeV neutron fluxes on the order of 2×10^{17} n/m^{2}s at the specimen, while the INS is designed for 14-MeV fluxes of up to 10^{18} n/m^{2}s at the specimen. Authorization for a Li(*d*,*n*) neutron source with a maximum flux of 10^{19} n/m^{2}s to be built at HEDL will be requested in the future. This source will have a 1 liter volume and distributed spectrum, which has been shown in the past year to be an excellent simulation of the fusion reactor damage spectrum.

Fission reactors are used in the program for testing of nickel-bearing materials because of the two-stage reaction for helium production in mixed fast and thermal reactor spectra. Thus, fission reactors permit simulation of helium/dpa damage accumulation similar to what will occur in fusion reactors. Unfortunately, this statement is true only for nickel-bearing alloys, and high-energy neutron sources are needed for all other materials.

The above sources will be used to accumulate neutron radiation data for materials development as well as to contribute to an understanding of damage analysis and extrapolation of fission reactor data to the high-energy fusion reactor spectra.